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Influence of using household biogas digesters on household energy consumption in rural areas—a case study in Lianshui County in China

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Abstract

Development of household biogas digesters in rural areas and integrated use of agricultural wastes has changed the structure of rural household energy consumption and greatly increased the application of highly efficient organic fertilizer, improved soil fertility and promoted sustainable agricultural development. This paper mainly discusses the influence of using household biogas digesters on household energy consumption in rural areas based on the data from the survey of rural household energy consumption and household biogas digesters in Lianshui County. The results showed that the construction of biogas digesters leads to the obvious decrease of per capita energy consumption in rural families and biogas mainly takes the place of some stalk and straw and a few firewood but does not substitute other forms of energy, especially commercial energy.

Keywords: Renewable energy; Biomass energy; Biogas digester; Energy consumption; Fuels

Contents

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1. Introduction

As the biggest developing country in the world, China has a population of 1.2 billion, 80% of which are living in rural areas. The issues of rural development, agriculture and farmers are of prime importance to China. Rural energy is the driving force for rural economic and social development. Energy development in rural areas is related to the upgrading of people's living standards, the improvement of ecological environment and the sustainable development of rural economy [1–4].

In order to achieve the goals of completely constructing a comparatively well-off society, the Ministry of Agriculture proposed the "Project of Biologically Enriching the Countryside". Using biogas digester as a channel not only changes the energy consumption structure in the countryside, but also stimulates the development of family breeding and cultivation; this also makes the heating system cleaner, the garden economy more efficient and agricultural production rid of pollution. This project has been carried out in many rural areas in China and the government will invest more capital into it. From 2003 to 2005, 11 million more rural families are supposed to use biogas digesters, accounting for 10% of the total, and the popularity of biogas digesters will reach 15% in some areas.

Most researches on the effectiveness of biogas digesters focus on investigating and evaluating some typical biogas projects [5–9]. Until now, no standard questionnaires have been conducted among individual families and there have not been any probing researches on how the constructions of biogas digesters by a large scale in rural areas affect household energy consumption.

Lianshui County, Jiangsu Province is a model county of the National Project of Biologically Enriching the Countryside. Through investigating questions about household energy consumption in this county, and analyzing the quantitative effect of biogas on household energy consumption, this paper provides basis for making policies about developing biogas digesters and about constructing "Project of Biologically Enriching the Countryside".

2. Data and methods

Lianshui County, lying in the east of Xu Huai plateau, is an under-developed county whose economic structure is based on agriculture. In 2001, it undertook the project of National Public Energy Facilities in Miniature in the Countryside and it took on the second phase of this project and built 3600 biogas digesters in six administrative villages. Four trained college students distributed the designed questionnaires in May 2003 to 312 families in Shuangma, Ji'an and Fanpu of the six villages. There were 59 questions about family economic conditions, energy consumption and the construction of biogas digesters in this questionnaire. The respondents were usually the householders or housewives. We used SPSS 10.0 (a software for statistical analysis) to process and analyze the data.

3. Status quo of the household energy consumption in rural families

The average population of the investigated families is 4.38 persons. Most families have four or five people (Table 1), among whom 96.2% are peasants and only a few are specialized farmers or administrative staff. In 2002, each household earned 9881.82 yuan, owned 0.343 hm^2 tillable land, harvest 478.5 kg grain plants, raised 4.96 pigs and consumed 372.69 kW h electricity.

In 2002, household energy consumption per capita in the countryside is 396.43 kgce (Table 2, we use 7000 kcal/kgce). Household energy consumption mainly depends on the local acquirable biotic substances, among which 54.83% is straw, 20.07% firewood and 9.50% biogas. However, commercial energy consumed in the countryside only accounts for 15.59%. Energy is primarily used for cooking, breeding and heating water, which respectively, accounts for 62.07%, 15.34% and 10.99% of the total consumption.

Statistics show that the energy consumption structure in Lianshui County is of a comparatively low level, in which non-commercial energy is dominant, and is mainly used for such fundamental needs as cooking and breeding. According to the local situation, the thermal conversion rate of straw and firewood is 18%, coal 22%, LPG (coal gas or natural gas) 60%, from which we can calculate the values of characteristic indicators of energy consumption in rural families [9], i.e. effective heat consumption for livelihood per capita per day (EHC) is 83.1 kgce, the proportion of commercial energy in EHC (PCE) is 11.6%, annual electricity consumption for livelihood per capita (AEC) is 85.09 kW h. Table 3 presents the characteristic indices of yearly rural energy consumption nationwide and in some

Table 1
The sample demographic characteristics

Number of persons per household	1	2	3	4	5	6	8	10
Sample size	4	26	58	84	72	46	6	2
%	1.3	8.3	18.6	26.9	23.1	14.7	1.9	0.6

Table 2
Per capita rural household energy consumption in 2002 (kgce). Electrical energy includes the energy required to produce electricity (1 kW h = 0.392 kgce)

	Firewood	Straw	Biogas	Coal	Kerosene	LPG	Electricity	Total
Lighting	–	–	0.79	–	0.01	–	30.18	30.98 (7.82%)
Cooking	55.28	150.69	18.59	11.58	–	5.72	4.21	246.07 (62.07%)
Breeding	24.28	34.07	1.51	0.92	–	0.03	–	60.82 (15.34%)
Heating water	–	25.23	15.26	2.97	–	0.13	–	43.58 (10.99%)
Remainder	–	7.36	1.56	5.95	–	0.1	–	14.98 (3.78%)
Total	79.57 (20.07%)	217.35 (54.83%)	37.67 (9.50%)	21.42 (5.40%)	0.01 (0.00%)	6.02 (1.52%)	34.39 (8.67%)	396.43 (100.00%)

provinces like Jiangsu [10]. We can see from the table that the effective energy consumption in the countryside of Lianshui County is comparatively high, which is mainly because farmers there raise quite a lot of pigs (4.96 pigs per household); however, commercial energy only accounts for as low as 11.6% of the effective heat, which is due to people's low income and inability to afford LPG or coal; the consumption of electric power per capita is obviously lower than the average level of Jiangsu Province in 1997, which is determined by the underdevelopment of the local areas.

4. The influence of biogas digester development on the energy consumption in rural areas

Through comparison between the energy consumption per capita in families possessing biogas digesters and in those without (Table 4), we can find the following differences:

Table 3
The values of characteristic indices of rural household energy consumption in some areas

	Lianshui County	Jiangsu Province [11]	Zhejiang Province [12]	Shandong Province [12]	All countryside [9]
Year	2002	1997	1994	1995	1996
Per capita income (RMB)	2256	3270	2225	1715	1578
EHC (kgce)	83.1	66.62	61.14	65.88	69.6
PCE (%)	11.6	27.5	24.2	20.4	42.4
AEC (kW h)	85.09	97.0	96.5	71.5	79.64

Table 4
Per capita rural household energy consumption between household with biogas digester and household without biogas digester in 2002 (kgce)

		Firewood	Straw	Biogas	Coal	Kerosene	LPG	Electricity	Total
Household with biogas digester	Lighting	–	–	1.22	–	0.02	–	9.22	10.46
	Cooking	54.20	107.38	23.18	11.48	–	5.54	1.16	202.94
	Breeding	24.87	37.69	2.36	1.15	–	0.05	–	66.12
	Heating water	–	15.85	19.91	2.32	–	0.12	–	38.20
	Remainder	–	7.10	3.63	8.33	–	0.12	–	19.18
	Total	79.07	168.02	50.30	23.28	0.02	5.83	10.38	336.90
Household without biogas digester	Lighting	–	–	–	–	0.01	–	11.21	11.22
	Cooking	62.90	238.07	–	13.01	–	6.74	1.86	322.58
	Breeding	26.08	31.60	–	0.61	–	–	–	58.29
	Heating water	–	43.38	–	4.45	–	0.18	–	48.01
	Remainder	–	8.55	–	2.30	–	0.07	–	10.92
	Total	88.98	321.60	–	20.37	0.01	6.99	13.07	451.02

1. The energy consumption per capita in families possessing biogas digesters is 336.9 kgce, while that in those without is 451.0 kgce. This indicates that energy consumption in families possessing biogas digesters decreased remarkably and that burning biogas turns out higher heat efficiency to meet household useful heat requirement.
2. The consumption of stalk and straw by the two kinds of families is 168.0 and 321.6 kgce, respectively. Biogas mainly substitutes stalk and straw and small amount of firewood.
3. Because of the seasonality of biogas production and the features of its usage, it can only partly substitute straw and stalk. For example, when biogas has not been made out in winter, or great firepower is needed, we should use firewood or stalk and straw instead of biogas. Data show that the substitutes equal to half of the former amount of stalk and straw.
4. Biogas does not remarkably substitute other forms of energy except firewood and straw. Even though biogas equals to LPG in a sense, it has not taken the place of the latter, because LPG is not commonly used in the countryside, only used in a few families with high income or under special conditions.
5. Table 5 shows the useful heat of various forms of energy in cooking, breeding or heating water. The useful heat per capita in families with biogas digesters is 83.3 kgce and that in families without is 82.6 kgce. In satisfying fundamental useful energy requirement, the useful heat provided by biogas substitutes that provided by stalk and straw and a small amount of firewood; the useful heat provided by other energy does not change much.
6. Table 6 shows where stalk or straw is used. Most families with biogas digesters use straw and stalk in fields as organic fertilizer, which occupies 42.76% of the total; those families without biogas digesters mainly use straw and stalk as fuel, and use much less as organic fertilizer. Therefore, constructing biogas digesters is an effective measure for reusing straw and stalk as organic fertilizer in fields

Table 5
Per capita rural household energy consumption by energies between household with biogas digester and household without biogas digester in 2002 (kgce)

	Firewood	Straw	Biogas	Coal	Kerosene	LPG
Household with biogas digester	14.23	30.24	30.18	5.12	3.50	83.27
Household without biogas digester	16.02	57.89	–	4.48	4.19	82.58

Table 6
The use of crop-straw between household with biogas digester and household without biogas digester in 2002 (kg)

	Used in fields as organic fertilizer	Used as fuel	Others	Total
Household with biogas digester	1211	1148	226	2585
Household without biogas digester	868	2974	227	4069

[13]. Statistics also reflects that families with biogas digesters spend near 100 yuan less money than those without.

7. Most peasants also agree on constructing biogas digesters. Among the investigated families, 48.7% like using biogas and few like using LPG, which is just opposite to the result of the survey done in Yangzhong, Jiangsu [10]. This is because the income of Lianshui County is comparatively low and the price of LPG is high; people cannot find many places to buy or recharge LPG and therefore most peasants are not willing to spend money on it. Those who love using LPG are comparatively well-off and do not like using biogas since it is not as clean and convenient as LPG. When asked whether it is wasteful to build biogas digesters, 68.3% families provided negative answers, 73.7% think it convenient to use biogas and nearly half of the families without biogas digesters decide to build one.

5. Conclusions

According to the statistics, rural household energy consumption in Lianshui County, Jiangsu Province in China depends mainly on the available local biomass energy and is primarily for such basic needs as cooking and breeding livestock. The construction of biogas digesters leads to the obvious decrease of per capita energy consumption in rural families. Biogas mainly takes the place of some stalk and straw and a few firewood but does not substitute other forms of energy, especially commercial energy. Families with biogas digesters use most of the stalk and straw as organic fertilizer in fields. Rural families give common approvals to building biogas digesters. The survey proves that biogas digesters can effectively help improve the rural energy consumption structure, increase the quality of family life, cut down the total consumption of energy, increase the amount of straw and stalk used in fields, decrease the usage of fertilizer, and that most peasants in underdeveloped areas agree on developing biogas digesters.

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